Information provision strategy for congestion mitigation

Zhandong Xu

Joint work with Junfeng He (Undergraduate student)

School of Transportation and Logistics

Southwest Jiaotong University

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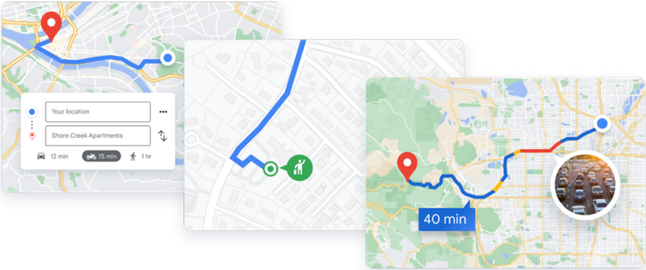
Outline

1. Introduction

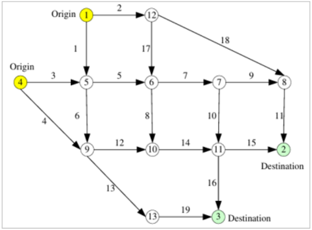
Motivations

- Information Paradox (Acemoglu et al., 2018): A larger information path set possibly leads to increased congestion.
- Information penetration: How many drivers should be informed? $\Rightarrow$ Fairness
- Restricted information set: How many paths should be posted? $\Rightarrow$ Unawareness
- Differentiated information provision: Users have differing information sets.



1. Introduction

Nguyen-Dupuis network:



O\D	2	3
1	900	300
4	300	700

Travel demand for each OD pair

O-D	Route	Node sequence	O-D	Route	Link sequence
	1	1-12-8-2		6	1-5-9-13-3
	2	1-5-6-7-8-2		7	1-5-6-7-11-3
(1, 2)	3	1-5-6-7-11-2	(1, 3)	8	1-5-9-10-11-3
	4	1-5-9-10-11-2		9	1-12-6-7-11-3
	5	1-12-6-7-8-2		10	1-5-6-10-11-3
	11	4-9-10-11-2		16	4-9-13-3
	12	4-5-6-7-8-2		17	4-9-10-11-3
(4, 2)	13	4-5-6-7-11-2	(4, 3)	18	4-5-9-13-3
	14	4-5-9-10-11-2		19	4-5-6-7-11-3
	15	4-5-6-10-11-2		20	4-5-9-10-11-3

Potential path set for each OD pair

2. Formulation

Bi-level optimization for deriving optimal information provision strategy:

$$\min \quad F(x,\tau) = \sum_{a\in A} x_a t_a(x_a) + \beta \sum_{r\in R}\sum_{s\in S}\sum_{\pi\in\Pi_u^{r,s}} (1-\tau_\pi^{r,s})$$

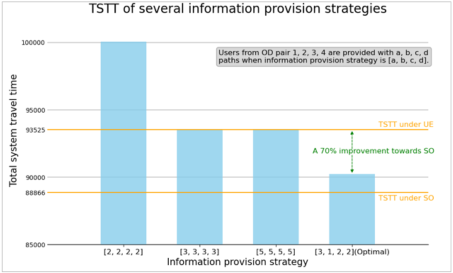
$$\text{s.t.} \quad \begin{cases} \displaystyle\sum_{\pi\in\Pi_u^{r,s}} (1-\tau_\pi^{r,s}) \geq l & \forall r\in R, \forall s\in S \\ \displaystyle\sum_{\pi\in\Pi_u^{r,s}} (1-\tau_\pi^{r,s}) \leq u & \forall r\in R, \forall s\in S \end{cases} \tag{1}$$

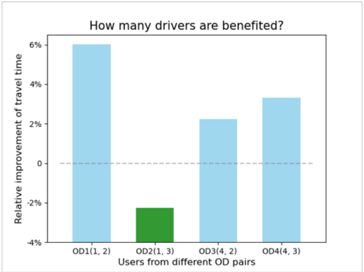
where $x = x(\tau)$ is implicitly determined by:

$$\min \quad f(x,\tau) = \sum_{a\in A} \int^{\sum_{r\in R}\sum_{s\in S}\sum_{\pi\in\Pi_u^{r,s}} \delta_\pi^{r,s} h_\pi^{r,s}} t_a(x)\, dx$$

$$\text{s.t.} \quad \begin{cases} \displaystyle\sum_{\pi\in\Pi_u^{r,s}} h_\pi^{r,s} = q^{r,s} & \forall r\in R, \forall s\in S \\ h_\pi^{r,s} \geq 0 & \forall r\in R, \forall s\in S, \forall\pi\in\Pi_u^{r,s} \\ \tau_\pi^{r,s} h_\pi^{r,s} = 0 & \forall r\in R, \forall s\in S, \forall\pi\in\Pi_u^{r,s} \end{cases} \tag{2}$$

$\tau_\pi^{r,s} = 0$ if user is aware of path $\pi \in \Pi_u^{r,s}$ connecting OD pair (r, s); $\tau_\pi^{r,s} = 1$ otherwise.





OD pair	**(1, 2)**	**(1, 3)**	**(4, 2)**	**(4, 3)**
Shortest travel time under UE	42.95	42.39	42.54	41.97
Shortest travel time under OIPS	40.37	43.35	41.59	40.58

The shortest travel time for each OD pair under user equilibrium(UE) and optimal information provision strategy(OIPS) flow pattern

- Bounded Rationality: Travelers may not choose the shortest path despite receiving path information. Modeling this behavior can effectively mitigate the congestion exacerbated by the concentration caused by traveler's similar choices.
- Costly Information: Fees can be implemented for information of critical paths. This encourages travelers to choose suboptimal routes, alleviating congestion on key paths and promoting a more balanced traffic distribution, ultimately guiding the network toward a system optimal state.
- Differentiated User Type: In addition to varying the quantity of path information, we can also differentiate its content. For travelers of type A, information on the 1st, 2nd, and 4th paths can be provided, while travelers of type B can receive information on the 2nd, 3rd, and 5th paths.

Thanks for your attention!

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Zhandong Xu, Assistant professor
School of Transportation and Logistics
Southwest Jiaotong University
Email: zhandong.xu@swjtu.edu.cn
Phone: +86 15884578722

西南交通大学 交通运输与物流学院
Southwest Jiaotong University School of Transportation and Logistics

Reference I

Acemoglu, D., Makhdoumi, A., Malekian, A., Ozdaglar, A., 2018. Informational braess' paradox: The effect of information on traffic congestion. Operations Research 66, 893–917.